THE UNIVERSITY OF ALBERTA

GENETIC AND ENVIRONMENTAL VARIANCE AND COVARIANCE IN BEEF CATTLE PERFORMANCE CHARACTERISTICS

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ABSTRACT

The effect of year, breed, and sex on preweaning and post-weaning performance characteristics was studied, utilizing records on 59 males and 78 females of Angus, Hereford, and Shorthorn breeding, born from 1956 through 1959. Analysis of variance was done within each sex, and results and corresponding means are presented. To eliminate the bias of unequal subclass numbers inherent in the means, best estimates for the main effects were obtained by the method of Least Squares. A t-test was used to establish significant differences between means adjusted by this method, and results were in close agreement with those obtained by analysis of variance of unadjusted data, indicating biases were probably not too important. Differences between years and breeds were apparent for most post-weaning characteristics and for some preweaning characteristics, and there were sex differences for all traits but birth weight.

In an attempt to establish relationships between performance traits, carcass characteristics, and nitrogen retention, a trial involving 19 animals representing four breeding groups was conducted. Because of the small number involved, no definite conclusions could be drawn, but some trends were apparent. Animals whose carcasses contained more fat had tended to gain slower and required more feed per unit gain than animals whose carcasses contained less fat. There was also a suggestion that animals which retained more nitrogen tended to have bigger rib-eye areas.

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INTRODUCTION

Variation in the rate with which beef cattle grow has been amply demonstrated. A newer and perhaps more important concept is the variation between animals in the amount of feed required per unit gain. A number of explanations for this variation can readily be deduced, but little research has been done to establish these explanations as facts.

In general, variation in performance can be broken down into genetic and environmental effects. Genetic effects would include epistasis, dominance, overdominance and additive genetic effects, with remaining variation due to various environmental influences. To study genetic effects, as represented by breed differences, and various environmental effects, use was made of records of performance available for animals representing three beef breeds, born over a period of four years at the University's Livestock Research Farm.

Because certain genetic differences may express themselves as metabolic and physiological differences, a study was conducted on calves born in 1959 to evaluate the extent to which breed groups did differ. Since fat contains about 2.25 times as much energy as protein on a dry basis, it was expected that animals which tended to deposit more fat relative to lean would require more feed per unit gain. This may also have a bearing on protein utilization, with absorbed protein either being used to build new body protein or being deaminated and used for energy production, in which case a lowered nitrogen retention would result. It was hoped that the study would verify these expectations and clarify the

effects of the variables studied on efficiency of feed utilization and rate of gain.

LITERATURE REVIEW

I. GENETIC INFLUENCES ON PERFORMANCE

A. Heritability

Heritability is the fraction of observed variation that is due to additive genetic differences between animals. Shelby *et al*. (1960) reported values for heritability of gain on feed of 0.46, for final weight adjusted to 376 days of 0.55, and efficiency of gain of 0.31. Swiger (1961) estimated heritabilities with their standard errors for birth weight of 0.22 ± 0.10, weaning weight of 0.25 ± 0.11, and 140-day feedlot gain of 0.40 ± 0.14. Koch and Clark (1955) reported essentially similar values. Marchello *et al*. (1960) reported the heritability of 18 month weight as 0.36. This is more reasonable than values obtained by Donald (1958), which ranged from 0.84 to 0.96.

Earlier estimates of heritability for various characteristics were reported by Knapp and Clark (1950), and Warwick and Cartwright (1955). Both groups reported values which were considerably higher than those already cited. However, the results reported in recent work using refined techniques are in good agreement, and additive genetic differences appear to account for 20 to 50% of the observed variation between animals for various traits.

B. Breed and Sire Differences

Damon *et al*. (1959) found a significant or highly significant difference between breeds for each of the performance

traits they considered. MacDonald et al. (1959) reported no differences between crossbred and purebred Herefords for either rate of gain or feed efficiency. It should be pointed out that the crossbreds began the test weighing 70 pounds more and ended it weighing 130 pounds more than purebreds. Both groups required 6.3 lb. of total digestible nutrients per pound of gain, but the crossbreds did gain 0.3 pounds per day more, and with 25 animals in each group, this must have approached significance. McCormick and Southwell (1957) found a significant difference between breeding groups for birth weight. Differences between breeds for weaning weights approached significance, but gain in the feedlot did not, probably because there were insufficient animals to detect a difference of only 0.16 lb. per day.

With pigs, Bowland and Berg (1959) found significant differences between strains for average daily gain and feed consumed per unit gain. Plank (1961) found differences in average daily gain and feed conversion significantly different between sire groups, involving 6 or 12 pigs per group but differences did not reach a level of significance where only 4 pigs per group were used. He emphasized, however, that boars of a particular breed showed no superiority over those of another breed and that important differences were those between sires, not breeds.

With beef cattle, Shelby et al. (1960) reported sire differences within lines were more important than line differences. Bennett and Matthews (1955) also reported significant differences between sires in beef cattle for rate of gain

and efficiency of feed utilization. Koch and Clark (1955) reported significant differences between lines as well as between sires within lines for birth weight, weaning weight, weaning score, yearling weight and yearling score. Line differences were greater than sire differences except for birth weight and weaning score. It seems that differences between sires within a breed or line are as important as differences between breeds, and that performance of the offspring may be more closely related to the particular sire used than to the breed he represents. Putting it another way, it would seem that genetic differences between breeds of a similar type (i.e., beef cattle) are not highly related to performance.

II. ENVIRONMENTAL INFLUENCES ON PERFORMANCE

A. Effect of Year

Because various environmental factors and, in some cases, sires change from year to year, it is of interest whether these changes have much effect on the performance of animals. McCormick and Southwell (1957) reported significant year effects for slaughter grade, dressing per cent, carcass grade, and feedlot gain. Birth weight and weaning weight differences were very nearly significant. They used different sires in different years which could account for these differences, although the carcass differences may indicate different feeding or management practices. The authors offered no explanation for these differences. Shelby, *et al*. (1960) also reported highly significant differences between years for all characteristics studied, but because

a fifteen year period was included in the study, many sires and climatic conditions would have been represented, and differences due to year effects would be expected. Similar results are reported by Peacock, _et al_. (1960) and Koch and Clark (1955).

B. Effect of Sex

Differences in birth weight between sexes have generally been reported as being small and non-significant. By weaning, males are significantly heavier and continue to gain faster. This is in accordance with work cited by Hitchcock _et al_. (1955), Pierce _et al_. (1954), and McCormick _et al_. (1956). Bennett and Matthews (1955) reported males had a highly significant advantage over females for rate of gain and efficiency of gain. Males gained 0.66 pounds per day more and gained 4.63 pounds more per 100 pounds T.D.N. consumed. Peacock _et al_. (1960) also found highly significant differences in weaning weight and slaughter grade between sexes. Males were heavier at weaning while females had the higher slaughter grade because they matured more quickly and put on more fat.

III. RELATIONSHIPS AMONG PERFORMANCE CHARACTERISTICS

The relationships between preweaning and post-weaning performance have been studied to determine the feasibility of selecting animals at weaning which will perform best after weaning. Koch and Clark (1955) reported the phenotypic correlation among paternal half-sibs as being 0.34 between birth weight and yearling weight, 0.04 between birth weight and gain from weaning to one year, -0.33 between weaning weight and gain from weaning to one year, and -0.36 between

gain from birth to weaning and gain from weaning to one year. These values are all significantly different from zero. They obtained very similar values for correlations within groups of calves born in the same year and from dams alike in ages.

Pierce, et al. (1954) report a non-significant correlation between suckling gain and gain per day from birth to the end of test. Black and Knapp (1936) obtained a correlation of -0.36 between gain from birth to weaning and gain from weaning to slaughter, the same as that reported by Koch and Clark. Although this accounts for only 13% of the variation, it is significant that calves which perform better before should tend to perform poorly after weaning. It also suggests that selection for weaning weight would not be an efficient means of improving post-weaning performance.

The relationship between type score and performance has also been studied. Nelms and Bogart (1955) reported correlation coefficients between score at 500 lb. and gains on test as -0.29 and -0.32 for males and females respectively. The highest positive correlation between score at 500 lb. and any other characteristic was with age on test for males, where they found it equal to 0.15. Type score at 800 lb. showed a correlation with gains on test of 0.10 for males and 0.14 for females. None of these values is significantly different from zero. This is in agreement with MacDonald and Bogart (1955) who also reported non-significant correlations between score at 500 or 800 pounds and gains and feed efficiency. However, Black and Knapp (1936) reported correlations of 0.42 and 0.56 between rate of gain and feeder grade and between

economy of gain and feeder grade. This might indicate that the latter group used a more rational approach in establishing feeder grade than was used in later years in establishing type score.

Relationships between various post-weaning performance characteristics have also been studied. Nelms and Bogart (1955) reported a correlation of -0.16 between daily feed intake and T.D.N. per lb. gain[1] for males. For females they obtained a value of 0.39. Although neither value is significantly different from zero, the trend suggests that if animals have a constant maintenance requirement, those which consume more nutrients above maintenance utilize them differently than do those which consume less above maintenance.

The relationship between rate of gain and feed efficiency has been frequently reported. Feed efficiency is expressed either as T.D.N./gain, in which case the correlation is negative, or as gain per 100 lb. T.D.N., in which case the correlation is positive. That the sign will be as indicated is assured, because gain is being correlated with a ratio which involves gain in the denominator in the first case, giving a negative correlation, and involves gain in the numerator in the second case, giving a positive correlation. The correlations obtained will also vary somewhat with the feeding regime employed. Pierce _et al_. (1954) reported a

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[1]In this thesis the following abbreviations will be used: T.D.N.= total digestible nutrients, T.D.N. per lb. gain = T.D.N. required per pound gain, and A.D.G. = average daily gain.

correlation of -0.82 and the regression of economy of gain as -232.8, indicating that for an increase in rate of gain of 1 lb. per day there is a saving of 232.8 lb. of T.D.N. for each 100 lb. liveweight gain. Black and Knapp (1936) reported a correlation of 0.88 between average daily gain and economy of gain from weaning to slaughter. Relationships of the same general magnitude have been reported by other workers; Alexander *et al*. (1958), Nelms and Bogart (1955) and MacDonald and Bogart (1955).

Numerous other relationships have been reported with correlations varying from zero to nearly one; Black and Knapp (1936), Bennett and Matthews (1955), Hitchcock *et al*. (1955), Koch and Clark (1955), MacDonald and Bogart (1955), Nelms and Bogart (1955) and Orme *et al*. (1959). Most of these relationships have little practical significance either because of their small value or because of the nature of the characteristics correlated.

IV. RELATIONSHIPS OF METABOLIC AND PHYSIOLOGICAL DIFFERENCES TO PERFORMANCE

Attempts to relate certain metabolic and physiological differences with variation in performance have been made in various classes of animals. In cattle, most attempts have been made to relate levels of certain blood and urine constituents to an animal's performance or growth potential. Alexander *et al*. (1958) reported correlation coefficients of 0.54 and 0.37 for rate of gain with serum alkaline phosphatase and serum acid phosphatase levels respectively, and slightly higher values of -0.56 and -0.48 with feed per unit gain.

Differences in blood antigen reactivity and protein fractions obtained by electrophoresis have also been implicated; Ashton (1957) and (1959).

With rats, Connelly (1960) reported a within diet correlation between apparent digestible nitrogen retained and trial gains of 0.418. Plank (1961) found with pigs there was no relationship between digestion coefficient and average daily gain, feed per pound gain, average backfat thickness, or loin area. Insofar as breeding effects are concerned, Likuski (1959) reported with rats, variation in dry matter and energy digestibility were likely associated with between - litter variation, but he found a non-significant difference for nitrogen digestion or retention between replicates, which reflected differences in breeding. With pigs, however, he found differences between replicates for dry matter and energy digestibility, indicating between litter variation.

Studies to determine the influence of composition of gain, that is, the proportions of fat, lean, and bone, on efficiency and rate of gain have also been reported. Lassiter _et al_. (1960) found in mice individuals making the same daily gains showed real differences in the amount of body fat deposited. However, data was not included on amount of food consumed. Plank (1961) reported non-significant within replicate, genotype and sex correlations between average back fat, loin area, total R.O.P. score, and fat/lean ratio and average daily gain or feed per pound gain. He did find a number of significant gross correlations, however. With

beef cattle, Black and Knapp (1936) reported a correlation of -0.62 between weaning weight at 252 days and per cent of fat in the carcass at 900 pounds. They also reported a correlation of 0.66 between weaning weight and pounds carcass per 100 pounds T.D.N. Although no direct comparison is made, the implication is that because animals which are heavier at weaning have less fat at 900 lb. and are also more efficient in feed utilization, less feed per unit gain is required when the proportion of fat deposited is decreased. That this inference is correct is suggested by the work of Branaman (1936), who found that an increase in net energy consumed per 100 lb. gain was accompanied by an increase in fatness in beef steers. Brody (1945) offered an explanation for this occurrence. Animals may gain weight at various rates, but gain energy at the same rate, providing the composition of the gains is different. For instance, one gram of protein gain is associated with a gain of three grams of water, but one gram of fat gain is associated with very little water. Moreover, one gram of fat contains 2¼ times the energy of one gram of protein, so one gram of fat gain is calorically equivalent to about eight grams protein gain, including the associated water. Thus, one might expect a relationship between the amount of fat deposited, either absolutely or relative to the amount of lean, and feed required per unit liveweight gain.

EXPERIMENTAL

I. ESTIMATION OF GENETIC AND ENVIRONMENTAL PARAMETERS

A. Objects

The objects of this analysis were to determine:

1. the effects of year, breed, and sex on the performance of beef cattle, and

2. the relationships among various measures of performance, and the relationship among performance measurements in various periods of the animal's life.

B. Source of Data

Since 1954 some performance records were kept on individual animals in the University beef herds. During 1954 and 1955, there was experimentation on frequency of weighings, method of feeding, recording consumption, etc., and not until 1956 were procedures standardized. Records taken from 1956 through 1959 are comparable, although management changed somewhat during that time.

Calves were routinely weighed at birth. After about two months, weighings at two week intervals commenced. Animals were weaned on the weigh day nearest 180 days, except in 1959, when they were weaned at 180 days of age, and weaning weight was recorded. Weighings were continued until one year of age or until males reached 800 lb., females 750 lb., whichever was latest.

Following weaning, calves were individually full-fed twice daily. Concentrate mix and chopped hay were weighed to each calf separately at each feeding, and the amounts recorded. An attempt was made to maintain proportions of

concentrate to hay at two parts to one. Records were kept in the feed test period showing initial and final weight, average daily gain, and daily hay and daily grain consumption for each two-week period. Records were also summarized for average daily gain, average daily feed and feed per 100 pounds gain from weaning to one year and from 450 to 750 lb. for females, 500 to 800 lb. for males. Average daily gain from birth to weaning was also calculated. All animals of Aberdeen-Angus, Hereford, or Shorthorn breeding with complete records were included in the analysis, except the metabolism steers in 1959.

C. <u>Methods of Analysis</u>

Because both sexes of three beef breeds were represented in each of the four years, the records were analysed as a factorial experiment. The analysis was, however, conducted within each sex, so that effects removed were year effects, breed effects, and the year x breed interaction. Calculation of sums of squares was done on the University's LGP-30 digital computer, utilizing a special program written to analyse unbalanced factorial designs as outlined by Goulden (1956).

Because of the variation from 2 to 10 animals within each breeding group in any one year, means might not truly represent breed and year differences, being biased by unequal subclass numbers. Unbiased estimates for effects of year, breed, and sex were obtained by the method of Least Squares. The mathematical model was:

$X_{ijkl} = U + Y_i + B_j + S_k + E_{ijkl}$ where

X_{ijkl} was the value of the $ijkl^{th}$ calf for birth weight, adjusted 180 day wt., A.D.G. from 450-750 or 500-800 lb., T.D.N./gain, and T.D.N./day;

U = the best estimate of the mean of the population;

Y_i = the effect common to calves born in the i^{th} year;

B_j = the effect common to calves of the j^{th} breed;

S_k = the effect common to calves of the k^{th} sex;

E_{ijkl} = a random effect due to error.

Based on this mathematical model, 7 simultaneous equations were set up and solved by use of the LGP-30 digital computer, using a standard matrix inversion program. From the inverse elements and Total Mean Square of observed date, standard errors of the estimates were computed, and a t-test was applied between main effects.

II. METABOLISM AND CARCASS STUDIES

A. Object

The object of these studies was to determine the extent to which differences in carcass composition and nitrogen retention were associated with rate of gain and feed conversion.

B. Experimental Animals

A study was initiated in 1959 to determine whether the expected relationships between nitrogen utilization, carcass composition, and performance could be demonstrated. Because of the small number of animals in each herd, a definite restriction was placed on the number of animals available for this study. Therefore, five Holstein steers were included with the beef steers, comprising four Angus, four Shorthorns

and eight Herefords. The Angus and Shorthorn groups each represented one sire and the Herefords represented two.

In the course of the experiment, one Hereford steer died and one Shorthorn became ill. Although the Shorthorn partially recovered and was eventually marketed, data from him was not included in the analysis. Thus, the final lot consisted of five Holstein, four Angus, seven Hereford, and three Shorthorn steers, a total of only nineteen animals.

C. Experimental Procedure

When experimental animals reached a weight of approximately 500 lb. they were subjected to a seven day nitrogen digestibility and retention trial, the conventional quantitative collection method being employed. During the trial, animals were placed in stanchions in the beef barn, University Livestock Research Farm, bedded with shavings, and fed and watered twice daily. The feed was the same as the animals had been getting previously, consisting of one part good quality hay and two parts, by weight, of concentrate mix. Concentrate mix was made up as indicated in Table 1. Feces were collected by the method outlined by Noller et al. (1959), but bags were made of 10 mil polyethylene and were slightly larger in size. Bags were supported by a specially designed harness which also supported the urine collection apparatus. Because of the high cost and limited life of the bags, they were replaced in the latter part of the trial with cloth bags fitted with 4 mil plastic liners, and this was found to be more satisfactory.

Urine was collected by means of a specially designed rubber funnel, with a length of rubber tubing leading to a covered polyethylene pail in the gutter. To avoid ammonia losses, 100 ml. of 50% sulfuric acid was placed in the pail. Urine volume was determined in ml., using a 2 litre graduated cylinder. A two per cent aliquot was taken for analysis. Some samples remained in the laboratory for considerable lengths of time after analysis, but they were still acidic and no ammonia fumes could be detected.

TABLE 1: COMPOSITION OF CONCENTRATE MIX

Oats	1000 lb.[1]
Barley	580 lb.
Wheat	250 lb.
Linseed Oil Meal	100 lb.
Soybean Oil Meal	50 lb.
Bonemeal	10 lb.
Salt	10 lb.
Vitamin A (10,000 I.U./gram)	½ lb.

[1]In 1956 and 1957, 100 lb. molasses replaced 100 lb. Oats.

Feed and feces were weighed to the nearest 10 grams. Feces bags were weighed before attachment, and again with contents, and weight of feces determined by difference. A composite sample of about 100 grams, weighed to 0.1 gm. was taken from each collection, dried as per method A of Bratzler and Swift (1959), ground, and analysed for nitrogen.

D. Analysis of Feces and Urine

After drying, feces samples were allowed to come to moisture equilibrium with the atmosphere for at least a week, at which time they were weighed and per cent dry matter for each collection calculated. Samples were then ground through a 40 mesh screen in a Wiley micro-mill and stored in glass jars until nitrogen determinations were made. Nitrogen determinations were according to A.O.A.C. methods, with the following modification: fifty ml. of concentrated sulphuric acid was used for digestion, and a digestion time of two hours was allowed. With this modification, digests still appeared oily on cooling but checks between duplicates were very good.

Since volume of collected urine was determined rather than weight, nitrogen was determined for 5 ml. of urine and milligrams nitrogen per millilitre was calculated. Nitrogen excreted in the urine was thus calculated by volume produced times concentration per unit volume.

E. Carcass Data

All steers in 1959 were slaughtered at approximately 800 pounds. They were weighed at the farm in the morning, then taken to a local packing plant for slaughter. Carcass weights and grades were obtained, and after chilling 35 mm. color slides of the 10-11 rib cut were taken from which fat and lean were estimated as outlined by Schoonover and Stratton (1957), with slight modifications. A grid consisting of 1 inch squares was placed over the 10-11 rib cut and photographed at a standard distance. Resulting slides were

projected to actual size on a frosted glass top of a specially built table, and the areas determined by use of a planimeter.

Weights of one front quarter and the corresponding hind quarter of the chilled carcass were also obtained. Length was measured from the front of the first rib to the aitchbone. Dressing percentage was calculated on the basis of warm dressed weight and farm weight which was taken in the morning after feeding and before watering.

F. Analysis of Data

The only effect which could be studied in this trial was the effect of breed. Calculations were done on the LGP-30 digital computer, using a program for sums of squares and sums of products between treatments and within treatments. Also calculated were total and within breed correlation coefficients among all variables.

RESULTS AND DISCUSSION

I. ESTIMATION OF GENETIC AND ENVIRONMENTAL PARAMETERS

A. Means and Analysis of Variance

Records included in this analysis represented 59 males and 78 females. One additional female was included for birth weight, weaning weight, and average daily gain from birth to weaning.

For males, the form of analysis was as follows:

Source of Variation	d.f.
Year	3
Breed	2
Year x Breed	6
Error	47

For females, the form was:

Source of Variation	d.f.
Year	3
Breed	2
Year x Breed	6
Error	66

Means and significant differences are shown in Tables 2, 3, and 4.

(1) Effect of Year

Year effects are a composite of several effects which could not be readily separated in the data. For preweaning effects, differences between the sires used in different years would likely have had some effect. However, environmental differences between years are probably more important in the

TABLE 2: SUMMARY OF RECORD MEANS - BIRTH TO WEANING

	MALES			FEMALES		
	Birth Wt.	180 Day Wt.	A.D.G. Birth Weaning	Birth Wt.	180 Day Wt.	A.D.G. Birth-Weaning
YEAR	--	--	--	--	*	*
1956	61.9	403.6	1.90	67.4	400.3	1.85
1957	63.6	396.4	1.85	63.9	374.5	1.73
1958	67.7	396.9	1.83	66.1	384.9	1.77
1959	67.8	397.2	1.83	67.1	360.9	1.63
BREED	**	*	--	**	**	**
Angus	57.8	382.1	1.80	60.7	362.6	1.68
Hereford	74.4	423.9	1.94	70.8	398.0	1.82
Shorthorn	66.4	396.1	1.83	62.8	358.7	1.64
INTERACTION	--	--	--	--	--	--

* F is significant at the 5% point.

** F is significant at the 1% point.

TABLE 3: SUMMARY OF RECORD MEANS - WEIGHT-CONSTANT PERIOD

	MALES			FEMALES		
	A.D.G. 500 - 800 lb.	T.D.N. per 100 lb. gain	T.D.N. per day	A.D.G. 450 - 750 lb.	T.D.N. per 100 lb. gain	T.D.N. per day
YEAR	**	*	**	**	*	**
1956	2.23	464.4	10.29	1.79	554.1	9.82
1957	2.00	477.8	9.47	1.47	572.8	8.30
1958	1.95	485.1	9.34	1.58	492.7	7.76
1959	1.79	434.3	7.76	1.47	521.4	7.59
BREED	--	**	**	**	**	**
Angus	1.98	492.7	9.66	1.53	558.1	8.48
Hereford	2.00	432.4	8.60	1.63	496.0	8.04
Shorthorn	2.07	473.8	9.74	1.46	595.7	8.67
INTERACTION	--	--	--	--	--	*

* F is significant at the 5% point.

** F is significant at the 1% point.

TABLE 4: SUMMARY OF RECORD MEANS - WEANING TO ONE YEAR

	MALES		FEMALES	
	A.D.G. Weaning to 1 Yr.	T.D.N. per 100 lb. gain	A.D.G. Weaning to 1 Yr.	T.D.N. per 100 lb. gain
YEAR	**	**	**	**
1956	2.05	440.1	1.61	537.0
1957	1.95	446.6	1.41	518.3
1958	1.82	441.3	1.49	453.8
1959	1.79	376.7	1.40	449.7
BREED	--	**	**	**
Angus	1.88	445.4	1.46	504.8
Hereford	1.93	412.7	1.52	469.6
Shorthorn	1.92	430.1	1.38	508.5
INTERACTION	--	--	--	--

* F is significant at the 5% point.

** F is significant at the 1% point.

preweaning period. Thus, variations in the quantity and quality of winter feed for the cows, temperature and precipitation variations, and particular pasture conditions would all have contributed to variations in preweaning performance. However, a significant year effect in this period was obtained only for females.

In the post-weaning period, year effects would again reflect sire differences, but in addition, changes in management would be manifest. For instance, it was intended that concentrates and roughage were to be fed in the ratio of 2 to 1; in practice there was a ratio of nearly 3 to 1 in 1956 and about 1.6 to 1 in 1959 with 1957 and 1958 reasonably close to 2 to 1. This led not only to a significant decrease in grain consumption per day, but also a significantly lower average daily hay consumption in 1959. A drastic decrease of 24.6% for males, 22.7% for females in T.D.N. consumed per day between 1956 and 1959 resulted. This decrease in nutrient intake would be expected to have an influence on rate of gain and efficiency of feed conversion and may be the major factor contributing to the significant or highly significant year effects. Another contributing factor might be the disproportionate numbers of the three breeds from year to year.

(2) Effect of Breed

Significant breed differences may reflect true differences in the genetic constitution of the breed groups in this study but are probably more dependent on the particular sires used within each herd over the years. This analysis is based on only 47 Angus by five sires, 55 Herefords by five

sires and 35 Shorthorns by four sires.

Breeds differed in birth weight, weaning weight, efficiency of feed conversion, and T.D.N. consumed per day. In addition, there was a highly significant difference between breeds for average daily gain from 450 to 750 lb. for females only. The corresponding rate of gain from 500 to 800 lb. for males did not differ for the three breeds. The differences in rate of gain for females were not caused by differences between breeds in feed intake since Hereford females gained fastest but consumed least and Shorthorn females gained slowest but consumed most.

(3) Interaction Between Years and Breeds

In most instances, no interactions were apparent, being significant in only one case, for T.D.N. consumed per day by females. The reason for the interaction seems to have been a more drastic reduction in intake for Angus than for Shorthorns, moving the Angus from highest daily intake to second highest, and moving Shorthorns from second highest intake in 1956 and 1957 to highest intake in 1958 and 1959. Herefords consistently had the lowest daily nutrient intake.

B. Least Squares Estimates

The method of Least Squares was used to obtain unbiased estimates of the effect of year, breed, and sex on birth weight, weaning weight adjusted to 180 days, average daily gain in the weight-constant period of 500 to 800 lb. for males, 450 to 750 lb. for females, efficiency of feed conversion in the weight constant period, and T.D.N. consumed per day in the

weight-constant period. Estimates thus obtained are presented in Table 5.

To establish significant levels a t-test was applied between individual year effects, breed effects, and sex effects. Results are shown in Table 6. The reliability of this approach for year and breed effects might be questioned, because when there were differences between the two effects being tested, the Type I error rate would have been greater than indicated by the level of significance. This is discussed by Duncan (1955). However, with a maximum of two intermediate values for years and one for breeds, the error from this source would not be large. For sex effects, the method is correct. The agreement between these tests and analysis of variance of unadjusted data as presented in Tables 2 and 3 is good in most instances.

(1) Effect of Year

There was no significant difference between years for birth weight. Weaning weight, however, decreased considerably between 1959 and 1956 or 1957. The results of Table 2 would indicate that this was confined to the females and that the males actually showed no such drop.

Rate of gain during the weight constant period was highest in 1956, and dropped in subsequent years, the greatest drop occurring between 1956 and 1957. This paralleled the T.D.N. consumed per day, where a drop occurred in 1957 and again in 1959. In 1957 and 1958 daily nutrient intake was the same. As outlined previously, the drop in feed intake was

TABLE 5: ESTIMATES OF PARAMETERS BY LEAST SQUARES

	Birth Wt.	180 Day Wt.	A.D.G. Wt. Const.	T.D.N. per lb. Gain	T.D.N. per Day
MALES					
Angus	59.8	395.2	1.96	4.83	9.40
Hereford	72.7	441.3	2.05	4.21	8.80
Shorthorn	65.4	406.0	1.98	4.95	9.59
1956	65.4	417.9	2.23	4.72	10.48
1957	64.2	429.8	1.94	4.90	9.26
1958	66.7	414.4	1.97	4.58	9.04
1959	67.6	394.8	1.86	4.46	8.26
FEMALES					
Angus	58.7	359.2	1.53	5.63	8.62
Hereford	71.6	405.3	1.62	5.01	8.02
Shorthorn	64.3	370.0	1.55	5.75	8.81
1956	64.3	381.9	1.80	5.52	9.70
1957	63.1	393.8	1.51	5.70	8.48
1958	65.6	378.4	1.54	5.38	8.26
1959	66.5	358.8	1.43	5.26	7.48
MALES - FEMALES	1.1	36.0	0.43	-0.80	0.78

TABLE 6: RESULTS OF T-TEST FOR SIGNIFICANT DIFFERENCES

	Birth Wt.	180 Day Wt.	A.D.G. Wt. Const.	T.D.N. per lb. Gain	T.D.N. per Day
YEAR EFFECTS					
1956 v.s. 1957	--	--	**	--	**
1958	--	--	**	--	**
1959	--	*	**	--	**
1957 v.s. 1958	--	--	--	*	--
1959	--	**	--	**	**
1958 v.s. 1959	--	--	--	--	**
BREED EFFECTS					
Angus v.s. Hereford	**	**	--	**	**
Shorthorn	*	--	--	--	--
Hereford v.s. Shorthorn	**	**	--	**	**
SEX EFFECT					
Males v.s. Females	--	**	**	**	**

* t is significant at the 5% point.

** t is significant at the 1% point.

associated with a decreased daily grain allowance. In 1959, not only was daily grain consumption further decreased, but hay consumption was also decreased resulting in a further drop in T.D.N. intake.

The adjusted data of Table 5 suggest that the restriction of feed intake after 1957 resulted in improved feed conversion. However, the observed data of Table 3 show a different response by the two sexes, suggesting a possible sex x year interaction. The trend of improved conversion was not apparent as it was with the adjusted data.

(2) <u>Effect of Breed</u>

Differences between any one breed group and the other two were real, for birth weight. By weaning, the difference between Angus and Shorthorns had disappeared, although Herefords were still highly significantly heavier. This might be expected if the different breeds tended to grow at similar rates, because what constitutes a large relative difference at birth would be a much smaller relative difference at weaning.

Analysis of observed data showed a difference between breeds in average daily gains in the weight - constant period for females only. Shorthorn males were ranked as the fastest gainers while Shorthorn females were ranked as the slowest gainers. The Least Squares estimates placed Shorthorns second, only slightly ahead of the Angus, but there were no significant breed differences in this analysis.

Feed conversion and daily nutrient intake fall in line

with average daily gains. The difference between Angus and Shorthorns is non-significant, but Herefords had better feed conversion and consumed less nutrients per day. Their superior rate of gain and lower feed intake obviously must lead to better feed conversion.

(3) Effect of Sex

Bull calves and heifer calves differed only very slightly in birth weight, the difference being non-significant, but differences among breeds were significant. Apparently, genetic differences between breeds are more important for birth weight than differences between sexes. Differences in pre-natal environment provided by cows of different breeds and variation in the length of gestation might also have contributed to breed differences.

Because of the superior rate of gain of males, they were heavier at weaning. During the weight-constant period males consumed more nutrients per day than the heifer calves and their efficiency of gain was superior. The difference in daily nutrient intake may also be confounded with the weight range over which animals were tested, males being tested over a range 50 lb. higher than females. The superior gaining ability of the males would also contribute to greater efficiency, but the sexes differ in factors other than rate of gain, and these very likely are also important.

C. Analysis of Covariance

Analysis of covariance was conducted on observed data. Computations were done on the digital computer, utilizing

TABLE 7: SELECTED CORRELATION COEFFICIENTS AMONG PREWEANING AND POST-WEANING CHARACTERISTICS FOR MALES

	180 Day Wt.	A.D.G. Birth to Weaning	A.D.G. 500 - 800 lb.	A.D.G. Weaning to 1 Yr.	T.D.N. per lb. gain 500-800	T.D.N. per Day 500-800	T.D.N. per lb. gain Weaning to 1 Yr.
Birth Wt.	.321* .047	.154 .268*	.308* .555**				
180 Day Wt.		.984** .975**	.375** .341*		-.404** -.512**		
A.D.G. Birth to Weaning			.336* .330**				
A.D.G. 500 - 800 lb.				.657** .764**	-.786** -.517**	.412** .625**	
A.D.G. Weaning to 1 Yr.							-.462** -.283*
T.D.N. per lb. gain 500 - 800 lb.						.197 .370**	

* Significant at the 5% point.

** Significant at the 1% point.

TABLE 8: SELECTED CORRELATION COEFFICIENTS AMONG PREWEANING AND POST-WEANING CHARACTERISTICS FOR FEMALES

	180 Day Wt.	A.D.G. Birth to Weaning	A.D.G. 450 - 750 lb.	A.D.G. Weaning to 1 Yr.	T.D.N. per lb. gain 450-750	T.D.N. per Day 450-750	T.D.N. per lb. gain Weaning to 1 Yr.
Birth Wt.	.529** .557**	.368** .396**	.190 .305**				
180 Day Wt.		.983** .983**	.200 .367**		-.431** -.426**		
A.D.G. Birth to Weaning			.214 .362**				
A.D.G. 450 - 750 lb.				.612** .670**	-.757** -.536**	.355** .478**	
A.D.G. Weaning to 1 Yr.							.324** .176
T.D.N. per lb. gain 450 - 750 lb.						.298* .627**	

* Significant at the 5% point.

** Significant at the 1% point.

a program designed for analysis of variance and covariance. Results were used to calculate correlation coefficients, some of which are presented in Tables 7 and 8. Within Year and Breed correlations are presented in the upper line, Total or Gross correlations in the lower line.

(1) Birth Weight

Birth weight is not highly correlated with any other characteristic, although correlation coefficients are in most instances significantly different from zero. In males, birth weight accounts for only 10% of the variation in weaning weight, whereas for females it appears to account for 25%. However, the two correlation coefficients are not significantly different from each other. Because of this low relationship to weaning weight and also to post-weaning performance, there would seem to be little or no advantage in including birth weight in a selection program.

(2) Weaning Weight

Weaning weight would be an important consideration where a policy of selling calves at weaning is followed. It is also important in cases where calves are fed after weaning, because an animal which is heavier at weaning will have to gain less after weaning to get to a certain weight, thus saving time and feed. In addition, animals which were heavier at weaning tended to gain more rapidly in the weight-constant period, although the relationship was not strong. One might theorize that, because of the very high relationship between preweaning gain and weaning weight, animals which gained most rapidly before weaning tended to continue

to gain well after weaning.

Of interest as well is the relationship between weaning weight and feed conversion. This is almost identical for males and females. Although differences in weaning weight account for only 16% of the variation in feed conversion, it is important that heavier animals at weaning tend to convert more of their feed to gain over a weight-constant feeding period.

Although the effect of higher weaning weight is not great, it would appear to be sufficiently important that it would be worthwhile determining whenever possible, and to be included in a selection index.

(3) <u>Rate of Gain in a Weight-Constant Period</u>

Measuring rate of gain over a fixed weight range is probably the most reliable measure of an animal's growth potential. Pierce <u>et al</u>. (1954) cited support for this view. This is because an animal's growth and metabolic processes are related to its size, and, as Pierce <u>et al</u>. point out, bulls tend to grow at a constant percentage rate. Thus, although most workers report having used a feeding period of a certain number of days, measuring gains over a certain weight range is more valid. The ranges of 500 to 800 lb. for males and 450 to 750 lb. for females were selected because they permitted most animals to make an adjustment to post-weaning environment, yet end at a level well below the mature weight. The difference in weight between males and females at weaning is recognized, and a sufficiently long period is provided to allow an animal to show its ability.

Rate of gain in this period was therefore used as a standard to which gain in other periods was related. Average daily gain from birth to weaning was not a reliable indicator of an animal's ability to gain over a weight-constant period. Rate of gain from weaning to one year was more satisfactory in this respect, but still accounted for less than 45% of the variation.

(4) Efficiency of Feed Conversion in a Weight-Constant Period

As with rate of gain, measuring feed conversion over a weight-constant period is probably the most accurate. The weight ranges used here are again very satisfactory, because they allow adjustment after weaning but do not go so high that some animals may be fattening extensively rather than growing normally.

The relation of weaning weight to feed conversion has already been discussed. The relationship of rate of gain to feed conversion is also of interest. Over 55% of the variation in feed conversion can be accounted for by variation in rate of gain. This relationship has been questioned because rate of gain is correlated with a ratio of which it is the denominator. This tends to force the correlation toward -1.0, but only when feed intake is fairly constant among animals. It has been suggested that the relationship obtained is actually higher than warranted. This is, however, not the case. If, for instance, feed intake is controlled either physically or statistically, then the animals which gain more

rapidly must convert their feed more efficiently or it would be impossible for them to gain as rapidly.

The relationship found in the current study was slightly less pronounced than those generally reported in the literature. However, feed intake was not standardized, as the plan called for full hand feeding. Thus, variations between animals in voluntary feed consumption was considerable, thereby reducing the magnitude of the correlation. Nonetheless, the relationship is still a useful one and comes about because animals will consume only a certain quantity of feed. With this limitation on nutrients available, those which gain more rapidly must utilize them differently from animals which gain more slowly. Requirement of more nutrients per unit of gain does, however, not necessarily imply lower efficiency, a point which is discussed more fully later.

(5) Weaning to One Year of Age

Performance, as measured from weaning to one year of age, was not too highly related to performance as measured in the weight-constant period. For males, there is again the suggestion that animals which gain faster convert their feed to more gain. However, for females there is no relationship between gain and feed conversion. This could be the case if those which ate the most also put on most fat, but might also reflect differences in maintenance requirements. It also clearly indicates that correlating gain with feed conversion does not necessarily give a high negative value.

D. Summary and Conclusions

(1) Means and Analysis of Variance

Because the analysis was done separately for each sex, no comparison between sexes can be made with any certainty of arriving at the correct conclusions.

Year effects were apparent for females only before weaning, and for both sexes following weaning.

Breeds differed in birth weight, with Angus being lightest and Herefords heaviest. Males of the different breed groups gained at similar rates, and although Herefords were still heavier at weaning, differences were relatively smaller at weaning than at birth. Female Herefords, however, gained faster than Angus or Shorthorn females, and by weaning there had not been the levelling effect that occurred with males.

Males also gained at the same rate following weaning, whereas there were differences between breeds for females. For both sexes, Herefords consumed the least feed, but converted the largest proportion to gain.

(2) Least Squares Estimates

By the method of Least Squares a comparison of performance of the two sexes was obtained as well as breed and year effects. Unfortunately, the unadjusted data suggested that there might be a sex x breed or sex x year interaction for various traits. This method assumes that there are no interactions, so the results may not be completely realistic, although they are free of the bias of unequal subclass numbers.

Year effects and breed effects were similar to those obtained by analysis of variance of unadjusted data. Sexes

did not differ for birth weight, but males were 36 pounds heavier at weaning, and gained 0.43 pounds per day faster in the weight-constant period. Males also consumed 0.78 pounds T.D.N. per day more than females, but required 0.80 pounds T.D.N. per lb. gain less than females over the weight-constant period.

(3) Relationships Among Measures of Performance and Among Performance Measures in Various Periods

Birth weight was not related to post-weaning gains for either sex, but showed a small relationship to preweaning gains for females only. Weaning weight, on the other hand, was highly related to preweaning gains. Weaning weight accounted for 4 to 14% of the variation in gains in the weight-constant period, and for over 16% of the variation in feed conversion.

Average daily gains from weaning to 1 year of age were not highly correlated with average daily gains over the weight-constant period, and accounted for only 36 to 40% of the variation in the latter period.

The correlation of 0.4 between rate of gain in the weight-constant period and T.D.N. consumed per day was lower than expected. However, in line with expectations, animals which gained fastest tended to convert more of their feed to gain; variation in gain accounted for about 55% of the variation in feed conversion. On the other hand, animals which consumed more feed per day tended to convert a smaller proportion to gain. The correlation of 0.2 between T.D.N. per day and T.D.N. per lb. gain for males was not significant,

but the correlation of 0.3 for females was significant. This could indicate that animals which consumed more feed per day tended to fatten more than animals which consumed less.

II. METABOLIC AND CARCASS STUDIES AND PERFORMANCE

The means and standard errors of the means are presented in Tables 9 and 10 for metabolism and carcass data obtained in this trial. The standard errors of the means are based on five values for Holsteins, four values for Angus, seven for Herefords and three for Shorthorns.

A. Analysis of Variance of Data

The purpose of this trial was to determine whether genetic differences expressed themselves as metabolic or carcass differences, and to determine the relationships between the characteristics studied. Thus, the analysis of variance consisted of testing breed differences. Mean squares and "F" values are shown in Table 11. For those characteristics showing a significant F value, Duncan's Multiple Range Test, as outlined by Duncan (1955) and extended by Kramer (1956) for unequal subclass members, was applied with results as indicated in Table 12.

The per cent nitrogen digested approached significance between breeds. Differences for average daily gain were significant which could be attributed solely to the superiority of the Holsteins for this characteristic. Despite the superior gaining ability of the Holsteins, they were not superior in feed conversion. For *m. longissimus dorsi* area,

TABLE 9: MEANS FOR STEER METABOLISM AND PERFORMANCE DATA

	% N Digested	% N Excreted In Urine	% N Retained Basis Intake	% N Retained Basis Digested	A.D.G. 500-800 lb.	T.D.N. per 100 lb. gain 500-800 lb.
Holstein						
Mean	76.90	34.40	42.60	55.20	2.04	483.1
$S_{\bar{x}}$	1.35	2.32	2.66	3.21	0.098	26.4
Angus						
Mean	71.30	36.70	34.60	48.40	1.69	502.1
$S_{\bar{x}}$	1.52	2.60	2.98	3.59	0.109	29.5
Hereford						
Mean	75.70	42.40	33.40	44.10	1.66	473.7
$S_{\bar{x}}$	1.15	1.96	2.25	2.72	0.083	22.3
Shorthorn						
Mean	76.70	40.90	35.80	46.70	1.61	558.9
$S_{\bar{x}}$	1.76	3.00	3.44	4.15	0.126	34.1

TABLE 10: MEANS FOR STEER CARCASS DATA

	Eye Muscle Area (Sq.In.)	Fat Cover Area (Sq.In.)	Lean/Fat Ratio	% In Hind Quarter	Carcass Length (In.)	Dressing %
Holstein						
Mean	9.53	1.71	5.69	48.83	46.55	54.6
$S_{\bar{x}}$	0.36	0.19	0.23	0.36	0.71	0.78
Angus						
Mean	8.14	3.39	2.44	49.34	44.38	56.1
$S_{\bar{x}}$	0.40	0.22	0.26	0.40	0.79	0.88
Hereford						
Mean	9.19	3.52	2.63	49.84	44.79	56.2
$S_{\bar{x}}$	0.30	0.16	0.19	0.30	0.60	0.66
Shorthorn						
Mean	7.81	4.31	1.83	50.36	44.00	58.2
$S_{\bar{x}}$	0.46	0.25	0.29	0.46	0.91	1.01

TABLE 11: ANALYSIS OF VARIANCE OF STEER DATA

	Source of Variation	Mean Square	F
% N Digested	Breed	28.33	3.06
	Error	9.26	
% Excreted in Urine	Breed	72.52	2.68
	Error	26.99	
% Retained Basis Intake	Breed	89.44	2.52
	Error	35.45	
% Retained Basis Am't Digested	Breed	123.12	2.38
	Error	51.62	
Eye Muscle Area	Breed	2.79	4.36*
	Error	0.64	
Fat Cover Area	Breed	5.20	27.37**
	Error	0.19	
Lean/Fat Ratio	Breed	13.75	52.88**
	Error	0.26	
% of Carcass in Hind Quarter	Breed	1.79	2.84
	Error	0.63	
Carcass Length	Breed	5.63	2.25
	Error	2.50	
Dressing %	Breed	8.15	2.65
	Error	3.07	
A.D.G. 500 - 800 lb.	Breed	0.187	3.90*
	Error	0.048	
Efficiency of Feed Conversion	Breed	5449	1.56
	Error	3487	

* Significant at the 5% point.

** Significant at the 1% point.

TABLE 12: SIGNIFICANT DIFFERENCES BY DUNCAN'S MULTIPLE-RANGE TEST*

Eye Muscle Area

Holstein	Hereford	Angus	Shorthorn
9.53	9.19	8.14	7.81

Fat Cover Area

Shorthorn	Hereford	Angus	Holstein
4.31	3.52	3.39	1.71

Lean/Fat Ratio

Holstein	Hereford	Angus	Shorthorn
5.69	2.63	2.44	1.83

Average Daily Gain (500-800 lb.)

Holstein	Angus	Hereford	Shorthorn
2.04	1.69	1.66	1.61

* Means not underscored by the same line are significantly different from each other at the 5% level.

TABLE 13: SELECTED CORRELATION COEFFICIENTS BETWEEN METABOLIC, CARCASS, AND PERFORMANCE CHARACTERISTICS

	Within Breed	Total
% Retained (basis am't digested) with A.D.G.	.052	.385
% Retained (basis am't digested) with T.D.N./gain	.096	.059
% Retained (basis am't digested) with Lean/Fat Ratio	.104	.505*
% Retained (basis am't digested) with % Excreted in Urine	-.955**	-.952**
% Retained (basis intake) with % N. Digested	.492*	.477*
% Retained (basis intake) with % Excreted in Urine	-.860**	-.850**
% Retained (basis intake) with % Retained (basis am't digested)	.970**	.968**
% Excreted in Urine with Eye Muscle Area	-.499*	-.364
% Excreted in Urine with A.D.G.	.067	.367
% Excreted in Urine with T.D.N./gain	-.104	-.062
Fat Cover with Lean/Fat Ratio	-.624**	-.936**
Fat Cover with Dressing %	.497*	.667**
Fat cover with A.D.G.	-.490*	-.739**
Fat Cover with T.D.N./gain	.470	.392
Lean/Fat Ratio with T.D.N./gain	-.220	-.254
A.D.G. with T.D.N./gain	-.861**	-.671**
Actual Wt. with "Weigh-Tape" Weight	-.203	-.107

area of fat cover and lean/fat ratio, all of which are significant, there was some difference between the beef breeds as well.

B. Analysis of Covariance and Correlation Coefficients

A number of significant total correlation coefficients were obtained. However, these were often associated with a big difference between Holsteins and the beef breeds for the characteristics correlated, and the corresponding within breed correlations were very small. Selected correlation coefficients are shown in Table 13. Because of the small number of degrees of freedom available, only a few within breed correlations are significantly different from zero. Those which are not may still indicate trends, but it must be realized that these trends could be due to chance more than 5% of the time.

The relationships expected between proportion of nitrogen retained, rate of gain, and rate of feed conversion, and carcass data were not apparent. Nonetheless, some trends are interesting. There is an indication that, as Brody (1945) suggested, animals which deposit more fat require more feed per unit gain, as shown by a correlation of .470 between fat cover and T.D.N. required per 100 lb. liveweight gain. This trend is also shown by a slight correlation of -0.220 between lean/fat ratio and T.D.N. per 100 lb. liveweight gain. Fatter animals also tended to gain slower (r_{xy} = -0.490).

The proportion of nitrogen excreted in the urine accounted for 91% of the variation in nitrogen retention. There also appears to be a relationship between eye muscle area and

proportion of nitrogen retained as indicated by amount excreted in the urine, the correlation being -0.499.

The observed correlation between average daily gain and feed required per unit gain of -0.861 is in general agreement with values cited in the literature review and somewhat higher than the values reported in the previous section of this thesis. This may be the result of more standardization of feed intake for the metabolism steers than for animals in the remainder of this study.

An interesting comparison is the last one listed in Table 13. On the last weigh day before steers were shipped, a number of measurements were taken, including girth at the flank with a so-called weigh-tape. The actual weights fell in a range of 40 pounds, from 790 to 830 pounds. The range for the weigh-tape values was 130 pounds, from 790 to 920 pounds, with an error in one instance of 120 pounds. This, plus the correlation coefficient of -0.20 indicates that the weigh-tape has very little practical value.

C. Discussion of Results Obtained

A number of problems were encountered during the course of this study which have a bearing on the validity of the results.

As was mentioned previously, animals were stabled in stanchions during the trial and collecting apparatus was supported by a harness. This did not provide a familiar environment and caused considerable discomfort to the animal. The urine collection apparatus, in particular, caused a

great deal of discomfort and irritation to the animal. Although the apparatus was cleaned frequently, every one of the animals ended the trial with a very sensitive sheath; in at least one instance the whole area was a raw wound by the end of the seven days despite the use of rubbing alcohol and olive oil.

Under these conditions one would not expect that animals would digest or utilize their feed in a normal manner, and large variations in per cent nitrogen digested and retained might readily result. In addition, weight changes during the seven days on trial were very erratic, and did not reflect normal body growth. Changes varied from a gain of 20 lb. to a loss of 12 lb. Although a major portion of abnormal weight changes might be attributed to changes in fill of the animal, it is felt that in at least two instances part of the weight loss reflected a loss of body protein. An increase in fill results in a higher apparent digestibility, whereas a decrease in fill shows a lowered apparent digestibility.

One Hereford, which digested 77% of the nitrogen in the feed, showed a weight loss of 12 lb. The reasonable digestion coefficient indicates that loss of fill was not likely the complete cause for this weight loss. The other animal, a Shorthorn, digested 80.7% of the nitrogen in the feed, again indicating that loss of fill was unlikely, but it lost eight pounds. Both animals excreted over 50% of the nitrogen they consumed in the urine, whereas the highest excretion for any other animal was 44.6%, that animal also

having a weight loss of two pounds. Metabolism stalls might have provided more comfortable surroundings for animals and simplified collection of feces and urine.

Animals went on trial at 500 lb., varying the starting time from August to January. During this time, fluctuations in temperature in the barn were considerable, varying from over 75° F. to below freezing, and could have influenced the results.

The combined possible error from sources just discussed makes the validity of results questionable. Also, because of the small number of animals involved, no firm conclusions could have been drawn under the best of conditions.

Some of the observed trends, however, indicate that more detailed study with better facilities might be warranted.

GENERAL SUMMARY AND CONCLUSIONS

Performance records were available on 59 bulls and 78 heifers born in the University Livestock Research Farm Beef herds from 1956 through 1959. In all, 47 Angus by five sires, 55 Herefords by five sires and 35 Shorthorns by four sires were included in this study. Effects of breed and year were obtained by analysis of variance of observed data. Data was adjusted for the effects of unequal subclass numbers by the method of Least Squares, and t-tests were used to establish significant differences in the adjusted data.

In an attempt to determine the effects of differences in the proportion of nitrogen digested and retained on an animal's performance, a preliminary trial was set up in 1959. Included were four Angus steers, seven Herefords, three Shorthorns, and five Holsteins. Seven day digestion and retention trials were conducted when animals reached a weight of 500 lb. At 800 lb., animals were slaughtered and carcass data was obtained.

There were, in general, differences between breed groups for the various measures of performance. The exception was rate of gain for all periods for males only. In this study, differences were due to the superiority of Herefords, Angus and Shorthorns being more similar in most characteristics. This difference is, however, probably the result of use of better sires in the Hereford herd than in the Angus and Shorthorn herds, and may not represent an actual difference between the breeds as a whole.

The superior rate of feed conversion by the Herefords is the result of their consuming less T.D.N. per day while gaining as fast or faster than the other breeds. Whether this reflects a lower maintenance requirement or a difference in the type of tissue formed by the Hereford, or both, is not certain, but the Metabolism Steer carcass data does indicate that Herefords tended to have more lean relative to fat than did the Angus or Shorthorn.

Year effects were apparent for all post-weaning performance traits. This is attributed to the drastic reduction in feed intake between 1956 and 1959. The results obtained by the method of Least Squares suggest as well that the restriction of feed intake in 1958 and 1959 resulted in improved feed conversion. This again is probably because of a lower energy storage per unit gain; a unit of gain probably consisted of less fat and more water in the last two years than in the first two. The opposite occurred between 1956 and 1957.

Difference in birth weight between the two sexes was not apparent. However, because of the ability of males to gain faster, the difference in weaning weight was highly significant. Males also gained faster in the weight-constant period, consumed more feed per day, and gained more per unit feed consumed. The difference in feed conversion is partly due to the faster gains made by males, but probably also reflects metabolic differences between sexes. Females likely were fattening more than males and were thus storing more energy per unit gain than males. At the same time, they were

consuming less nutrients per day than males, leaving them with less above maintenance to convert into gain.

Although no firm conclusions can be drawn from results of the metabolism trial because of the small number of animals involved and difficulties experienced, some trends are interesting and suggest that further work might be indicated. The high relationship between per cent nitrogen retained and per cent excreted in the urine is a useful one, especially from the standpoint of further work, because of the relative ease of determining per cent excreted in the urine. The observed correlations between carcass characteristics, especially fat cover, and performance also appear very encouraging. More accurate methods of determining body fat, and a larger number of animals could produce some interesting and valuable results.

LITERATURE CITED

Alexander, G. I., Hugo Krueger, and Ralph Bogart. 1958. Rate and Efficiency of Gains in Beef Cattle V. Serum Phophatases of Growing Hereford and Angus Cattle. Ore. Agr. Exp. Sta. Tech. Bul. 42.

Ashton, G. C. 1957. Serum Protein Differences in Cattle by Starch Gel Electrophoresis. Nature 180:917.

Ashton, G. C. 1959. B Globulin Polymorphism and Early Faetal Mortality in Cattle. Nature 183:404.

Association of Official Agricultural Chemists. 1955. Official Methods of Analysis. 8th Ed. Washington, D. C.

Bennett, James A., and Doyle J. Matthews. 1955. Performance Testing Studies with Beef Cattle. Utah Agr. Exp. Sta. Bul. 377.

Black, W. H., and Bradford Knapp, Jr. 1936. A Method of Measuring Performance in Beef Cattle. Proc. Am. Soc. Animal Prod. 29:73.

Bowland, J. P., and R. T. Berg. 1959. Influence of Strain and Sex on the Relationship of Protein to Energy in the Rations of Growing and Finishing Bacon Pigs. Can. J. Animal Sci. 39:102.

Branaman, G. A., O. G. Hankins, and Lucy M. Alexander. 1936. The Relation of Degree of Finish in Cattle to Production and Meat Flavors. Proc. Am. Soc. Animal Prod. 29:295.

Bratzler, J. W., and R. W. Swift. 1959. A Comparison of Nitrogen and Energy Determinations on Fresh and Oven-Air Dried Cattle Feces. J. Dairy Sci. 42:686.

Brody, Samuel. 1945. Bioenergetics and Growth. Reinhold Pub. Co. New York. p 753.

Connelly, F. M. 1960. Dietary Protein Utilization and Thyroid Activity in Two Inbred Lines of Rats and their Reciprocal Crossbreds. M. Sc. Thesis. University of Alberta

Damon, R. A., Jr., S. E. McCraine, R. M. Crown, and C. B. Singletary. 1959. Performance of Crossbred Beef Cattle in the Gulf Coast Region. J. Animal Sci. 18:437.

Donald, H. P. 1958. Evidence from Twins on Variation in Growth and Production of Cattle. Proc. X Inter. Cong. Genetics. Montreal. 1:225.

Duncan, David B. 1955. Multiple Range and Multiple F. Tests. Biometrics 11:1.

Goulden, Cyril H. 1956. Methods of Statistical Analysis. 2nd Ed. John Wiley and Sons Inc., New York.

Hitchcock, Glen H., W. A. Sawyer, Ralph Bogart, and Lyle Calvin. 1955. Rate and Efficiency of Gains in Beef Cattle. III. Factors Affecting Weight and Effectiveness of Selection for Gains in Weight. Ore. Agr. Exp. Sta. Tech. Bul. 34.

Knapp, Bradford, Jr., and R. T. Clark. 1950. Revised Estimates of Heritability of Economic Characteristics in Beef Cattle. J. Animal Sci. 9:582.

Koch, Robert M., and R. T. Clark. 1955. Genetic and Environmental Relationships Among Economic Characters in Beef Cattle. I. Correlation Among Paternal and Maternal Half-Sibs. J. Animal Sci. 14:775.

Koch, Robert M., and R. T. Clark. 1955. Genetic and Environmental Relationships Among Economic Characters in Beef Cattle. II. Correlations Between Offspring and Dam and Offspring and Sire. Ibid 14:786.

Kramer, Clyde Young, 1956. Extension of Multiple Range Tests to Group Means with Unequal Numbers of Replications. Biometrics 12:307.

Lassiter, J. W., A. E. Cullison, and J. L. Carmon. 1960. Variations in Body Composition of Mice having the Same Average Daily Gain. J. Animal Sci. 19:769.

MacDonald, M. A., and Ralph Bogart. 1955. Relationship Between Rate and Efficiency of Gain and Type in Breeding Beef Cattle. N. Z. J. Sci. Tech. A, 36:460.

MacDonald, M. A., S. B. Slen, and H. J. Hargrave. 1959. A Comparison of Feedlot Performance and Carcass Characteristics of Charbray & Hereford with Hereford Steers. Can. J. Animal Sci. 39:14.

McCormick, W. C., and B. L. Southwell. 1957. A Comparison of Brahman Crossbred with British Crossbred Cattle. J. Animal Sci. 16:207.

McCormick, W. C., B. L. Southwell, and E. J. Warwick. 1956. Factors Affecting Performance in Herds of Purebred and Grade Polled Hereford Cattle. Georgia Agr. Exp. Sta. Tech. Bul. N. S. 5.

Marchello, J. A., D. W. Blackmore, and J. J. Urick. 1960. Heritability of 18 Month Weight of Heifers and the Relationship of this Weight to the Birth Weight of the Heifer's First Calf. Western Section Am. Soc. Animal Prod. Proc. 11:10.

Nelms, G. E. and Ralph Bogart. 1955. Some Factors Affecting Feed Utilization in Growing Beef Cattle. J. Animal Sci. 14:970.

Noller, C. H., M. C. Stillons, F. A. Martz, and D. L. Hill. 1959. Digestion Studies with Oat Silages Using a New Fecal Collection Technique. J. Animal Sci. 18:671.

Orme, L. E., A. M. Pearson, W. T. Magee, and L. J. Bratzler. 1959. Relationship of Live Animal Measurements to Various Carcass Measurements in Beef. J. Animal Sci. 18:991.

Peacock, F. M., W. G. Kirk, E. M. Hodges, W. L. Reynolds, and M. Koger. 1960. Genetic and Environmental Influences on Weaning Weight and Slaughter Grade of Brahman, Shorthorn, and Brahman-Shorthorn Crossbred Calves. Fla. Agr. Exp. Sta. Tech. Bul. 624.

Pierce, Cecil D., H. G. Avery, Martin Burris, and Ralph Bogart. 1954. Rate and Efficiency of Gains in Beef Cattle. II. Some Factors Affecting Performance Testing. Ore. Agr. Exp. Sta. Tech. Bul. 33.

Plank, R. N. 1961. Relationships of Feedlot Performance and Carcass Characteristics of Swine. M. Sc. Thesis. University of Alberta.

Schoonover, C. O., and P. O. Stratton. 1957. A Photographic Grid used to Measure Rib-Eye Areas. J. Animal Sci. 16:957.

Shelby, C. E., R. T. Clark, J. R. Quesenberry, and R. R. Woodward. 1960. Heritability of Some Economic Characteristics in Record of Performance Bulls. J. Animal Sci. 19:450.

Swiger, L. A. 1961. Genetic and Environmental Influences on Gain of Beef Cattle During Various Periods of Life. J. Animal Sci. 20:183.

Warwick, Bruce L., and T. C. Cartwright. 1955. Heritability of Rate of Gain in Young Growing Beef Cattle. J. Animal Sci. 14:363.